NASA Range Safety Program
2006 Annual Report

EMERGING TECHNOLOGY
PROCESSOR FOR REAL-TIME ATMOSPHERIC COMPENSATION IN LONG RANGE IMAGING

Range surveillance and launch tracking are critical components of space exploration because of their impact on safety, cost, and the overall mission timeline. Because of the difficulty of verifying a cleared range, launch delays are common and will increase as spaceports are developed in new areas. To expedite range clearance and enhance vehicle tracking, it is vital to see accurately and clearly through the atmosphere. However, the quality of images taken with long-range optical systems is severely degraded by atmospheric movements in the path between the region under observation and the imaging system. In fact, as distances increase, atmospheric turbulence is often the dominating source of noise in infrared and visible imaging applications.

Fortunately, image processing algorithms, such as the bi-spectrum speckle imaging method and control grid interpolation, have been developed to help compensate for these disturbances. Even so, these image processing algorithms by themselves are not enough. Specifically, atmospheric compensation algorithms are computationally intensive, which prevents even top-of-the-line personal computers from evaluating them in real time. The necessary algorithms can easily require several seconds to process a single frame and real-time video requires several dozen frames per second—a two order-of-magnitude difference! In 2005, a Phase I Small Business Innovation Research contract was awarded to EM Photonics, Inc. of Newark, Delaware to develop a processor for real-time atmospheric compensation in long-range imaging.

Phase I Approach

The technology being developed is an accelerated solver for a speckle imaging method developed by Carmen Carrano at Lawrence Livermore National Lab. The method takes several seconds of compute time on a modern personal computer to process one image frame. The Small Business Innovation Research approach is to reformulate the algorithm and implement it in hardware using a field programmable gate array as a reconfigurable computing device.

Field programmable gate arrays on the market today contain millions of logic blocks. Algorithms implemented in software languages such as C can be compiled to a direct implementation in field programmable gate array hardware with orders of magnitude performance improvement. The speckle imaging computational problem can be broken up and solved by many parallel hardware blocks in the array and the individual results recombined to produce the resulting image. The overall objective is to be able to process high definition 720p 60 frames per second video in real-time.

Phase I Results

In Phase I of the Small Business Innovation Research contract, EM Photonics was able to verify the approach by reformulating the algorithm and partially implementing it on a field programmable gate array resulting in a 40X speed improvement over the software only version. Only a small piece of the solver was actually implemented on the array.

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The bulk of the work in Phase I was benchmarking and reconfiguring the code to lend itself to field programmable gate array implementation. EM Photonics successfully met all the objectives for its 2005 Small Business Innovation Research Phase I contract.

At the final demonstration, they were able to process (albeit at 1 frame per second due to the limited implementation) high-definition recorded launch video samples to prove the increase in speed and image enhancement capabilities. An excerpt from one of these samples is shown in the photograph of the Pluto New Horizons spacecraft.

Phase II Goals

With the success of Phase I, EM Photonics submitted a Phase II proposal. The goal for Phase II is to complete the implementation of the entire algorithm in the field programmable gate array and achieve the real-time objective. The company is proposing to deliver a desktop workstation (personal computer) solution using a co-processing board developed for another product. The workstation could process video from a central control room type location either during or post launch working on recorded video. The company is also proposing to provide an integrated embedded solution suitable for attaching directly to an imaging system in the field. EM Photonics Phase II was selected for award with a contract expected in December 2006.

Currently there are no commercial systems available that provide this type of image enhancement and compensation for atmospheric disturbance. EM Photonics has other field programmable gate array based hardware accelerated solver commercial products on the market and, if successful with Phase II, has several potential customers for this product.